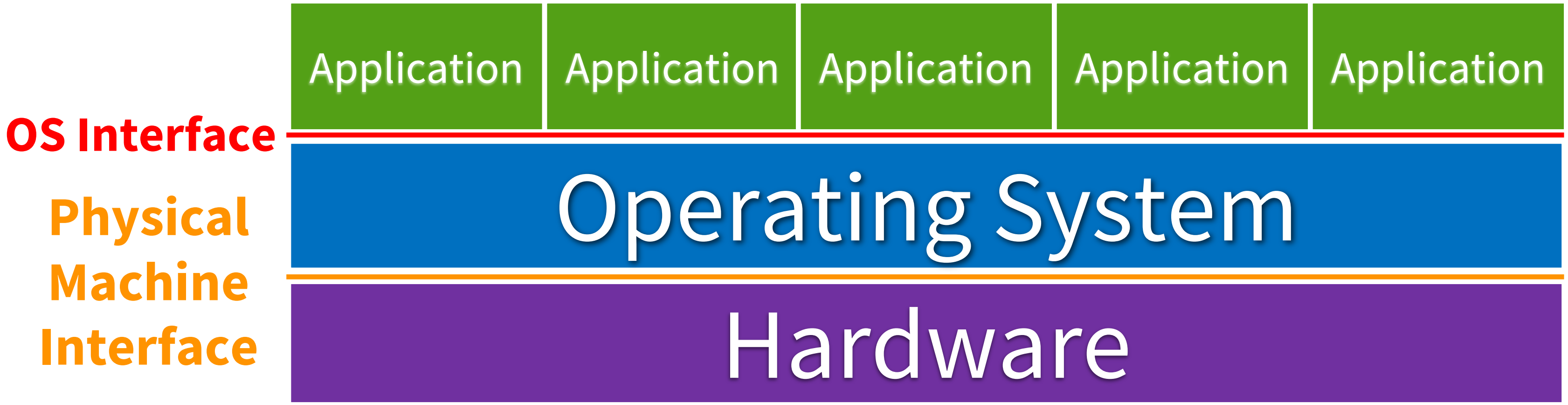
Introduction

CS 4410
Operating Systems

[R. Agarwal, L. Alvisi, A. Bracy, M. George,
F. B. Schneider, E. G. Sirer, R. van Renesse]

What an OS does

- Intermediates between programs and hardware
- OS creates an environment to execute programs *conveniently* and *efficiently*:
  - allocates resources (CPU, storage, ...)
  - controls programs
    - cooperation (sharing and synchronization)
    - isolation (protection and resource management)



Ways to view an OS

- **Services** it provides to programs
- **Components** implementing those services
  - Real hardware is difficult to use directly

Why Study OS?

Learn solutions to problems arising in all systems:

- Resource sharing (scheduling)
- Cooperation (concurrent programming)
- System structure (abstractions, interfaces)
- Performance (caching, locality)

Systems vs Programs (I)

How designing an OS differs from designing a program

- **Measure of success**: OS concerned with extensibility, security, reliability, …
- **External interface**: OS more complicated and subject to change. E.g. I/O devices
- **Structuring techniques**: OS employs
  - modules, layers, client-server, event-handler, transactions

Systems vs Programs (II)

How designing an OS differs from designing a program

OS must bridge mismatched performance characteristics

- Registers vs RAM vs Disk
- Phone vs Laptop vs Server

What makes systems complex?

Emergent properties: Evident only when components are combined.

Example: Millennium Bridge (London)

What makes systems complex?

Propagation of Effects: When small changes have disproportionate effects

Examples:

- Power failures in power grid
- Change auto tire size from 13” to 15”
  - » kills suspension
- Boeing 737 max 8 design
  - » 4^{th} generation of 737
  - » larger engines, mounted further forward and higher
  - » pushes up nose of jet
  - » compensated by sensors and software…

What makes systems complex?

Incommensurate Scaling: Different parts follow different scaling rules

Examples:

- Height limits on skyscrapers
- Size limits on cargo ships
  - » Horizon distance is linear in size of object
  - » Stopping distance is proportional to object volume
- Giant in Jack and the Beanstalk

How to Manage Complexity

- **Modularity**: Good modularity minimizes connections between components
- **Abstraction**: Separate interface from internals; separate specification from implementation
- **Hierarchy**: Constrains interactions so easier to understand

OS has many roles

Referee

- Manages shared resources: CPU, memory, disks, networks, displays, cameras, *etc.*

Illusionist

- Look! Infinite memory! Your own private processor!

Glue

- Offers set of common services
- Separates apps from I/O devices

OS as Referee

<u>*Resource allocation*</u>

- Multiple concurrent tasks, how does OS decide who gets how much?

<u>*Isolation*</u>

- A faulty app should not disrupt other apps or OS
- OS must export less than full power of underlying hardware

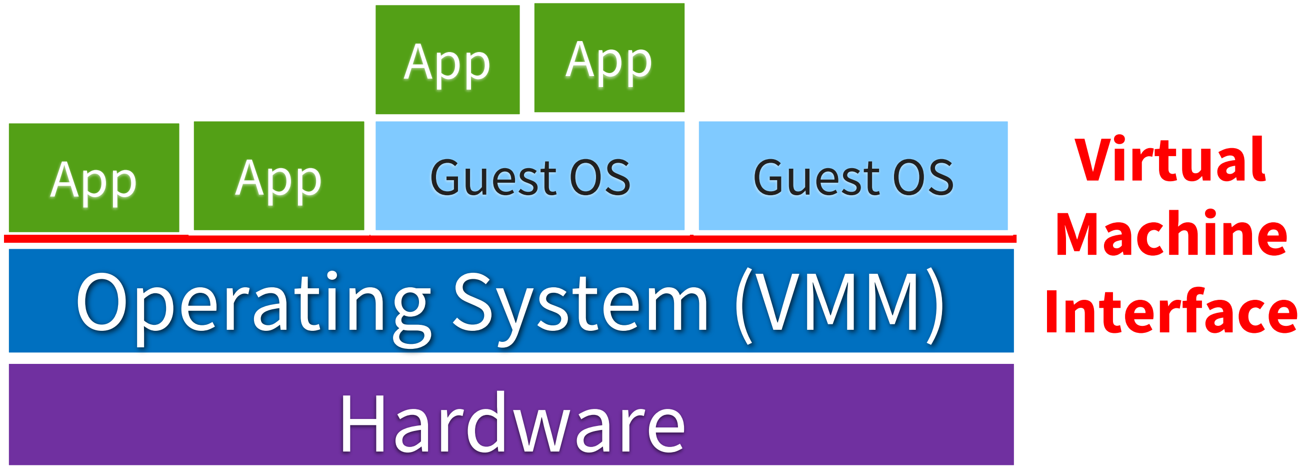
<u>*Communication/Coordination*</u>

- Apps need to share state

OS as Illusionist (1)

Virtualization: Resources seem present but aren't

- processor, memory, screen space, disk, network link
- the entire computer (*virtual machine*):
  - fooling the illusionist itself!
  - ease of debugging, portability, isolation



OS as Illusionist (2)

Abstraction: Enables new assumptions for clients

- Atomic operations
  - HW provides atomicity at word level
    - what happens during concurrent updates to complex data structures?
    - what if computer crashes during a file write?

- Reliable communication channels
  - At the hardware level, packets are lost…

OS as Glue

Simplify app design and facilitate sharing due to:

- send/receive of byte streams
- read/write files
- pass messages
- share memory

Decouples HW and app development

Issues in OS Design

- **Structure:** how is the OS organized?
- **Concurrency:** how are parallel activities created and controlled?
- **Sharing:** how are resources shared?
- **Naming:** how are resources named by users?
- **Protection:** how are distrusting parties protected from each other?
- **Security:** how to authenticate, authorize, and ensure privacy?
- **Performance:** how to make it fast?

Issues in OS Design

- **Reliability:** how do we deal with failures?
- **Portability:** how to write once, run anywhere?
- **Extensibility:** how do we add new features?
- **Communication:** how do we exchange information?
- **Scale:** what happens as demands increase?
- **Persistence:** how do we make information outlast the processes that created it?
- **Accounting:** who pays the bill and how do we control resource usage?